MEMOIR 1: MIAMI GEOLOGICAL SOCIETY

A SYMPOSIUM OF RECENT SOUTH FLORIDA FORAMINIFERA

by

W. D. Bock
W. W. Hay
J. I. Jones
G. W. Lynts
S. L. Smith
R. C. Wright

Edited by James I. Jones and Wayne D. Bock

Additional copies of this memoir are available from the Miami Geological Society, 10 Rickenbacker Causeway, Miami, Florida 33149, at $7.00 each.

DISTRIBUTION AND MODEL STUDIES ON FORAMINIFERA LIVING IN BUTTONWOOD SOUND, FLORIDA BAY

by

GEORGE W. LYNTS

DEPARTMENT OF GEOLOGY

DUKE UNIVERSITY

DURHAM, NORTH CAROLINA

ABSTRACT

Distribution of foraminiferal standing crop in Buttonwood Sound, Florida Bay, was investigated to define ecological factors controlling or influencing species distributions. A total of 74 samples were collected from a grid system consisting of 19 stations. Stations were occupied three times during August 1962, and once during February 1963. The following environmental parameters of the water-sediment interface were measured: depth, temperature, salinity, pH and Eh. Each sample was analyzed for foraminiferal standing crop and ratio of sand, silt and clay. Q-modal factor-vector analysis divided the standing crop into 17 faunal assemblages, consisting of three to five assemblages in a single collection. Distribution of most of these assemblages appeared to be controlled by an interaction of ecological parameters. A fauna which was related to sediment size and one which was related to bathymetry persisted throughout all collections. Distribution of foraminiferal species and environmental parameters indicated some species were influenced by the measured environmental parameters, but most species showed no such relationships. The faunal information indicated there was no simple linear relationship between distribution of Foraminifera and environmental parameters. Distribution of Foraminifera living in Buttonwood Sound was controlled by a complex interplay of physicochemical and biologic factors, only partially reflected by the measured parameters.

INTRODUCTION

This investigation is part of a project begun at the University of Wisconsin in the summer of 1958, to expand knowledge of Foraminifera living in Florida Bay and environs. Additional samples were collected during the winters of 1960, and 1963.

Benda and Puri (1962) described a similar foraminiferal fauna from the Cape Romano region, located about 80 miles north of Florida Bay on the west coast of Florida. Wilcoxon (1964) described the distribution of Foraminifera off the south Atlantic coast of the United States. Additional work on the foraminiferal fauna of Florida Bay was reviewed in Lynts (1962).

Seventy-four samples were collected from 19 stations located in Buttonwood Sound (Fig. 1). The 19 stations were occupied at three day intervals on August 14th, 17th, 20th, 1962, and once on February 9th, 1963. Two samples from the February 9th, 1963 collection were not used in the study. The majority of samples were collected using short cores, but a few were grab samples.

The relationship between foraminiferal species and physioco-chemical parameters was analyzed quantitatively to ascertain influence of ecologic factors on distribution of Foraminifera.

ACKNOWLEDGMENTS

The study was supported in part by a National Science Foundation Fellowship, Penrose Bequest Grant number 909-62 from the Geological Society of America and Public Health Service Grant number 1-Ti-DE-132-01. The Numerical Analysis Laboratory, University of Wisconsin, and Columbia Computer Center, Columbia University, furnished computer time. I wish to thank the Institute of Marine Science, University of Miami, for use of their facilities and equipment at various times during the study.

LOCATION

Buttonwood Sound is part of Florida Bay located south of the Florida Peninsula, lying between the Florida mainland and Florida Keys. Buttonwood Sound is in the southeastern part of Florida Bay, adjacent to Largo Key. It lies between 25° 5-8' North Latitude and 80° 26-29' West Longitude. Figure 1 gives the location of the stations.

METHOD OF STUDY

Upon completion of the survey of the foraminiferal fauna and ecological parameters of Florida Bay (Lynts 1961, 1962), it was decided to conduct a study of the benthonic faraminiferal standing crop of Buttonwood Sound. Samples were collected over a relatively short time period, on August 14th, 17th, 20th, 1962. This time interval was used because little was known about the rates of change of ecologic parameters and distribution patterns of organisms in Florida Bay (Greenfield and Oppenheimer, 1962, personal communication).

A sample design was formulated to obtain a valid series of the standing crop and environmental parameters. This consisted of a systematic stratified grid of stations approximately 900 meters apart which was randomly superimposed on the study area. Stations were marked with floats, and compass bearings were taken to allow reoccupation. Sediment cores, with an inside diameter of 4.8 centimeters, were taken at each station on the 14th, 17th, 20th of August 1962. Samples were preserved in a buffered formalin solution. At each station the following environmental parameters of the water-sediment interface were measured: 1) depth, 2) temperature, 3) salinity, 4) pH and 5) Eh (Tables 1, 2, 3, 4 and 5). These parameters were measured in the field, because many of them change rapidly when removed from in situ position (Oppenheimer, 1963, personal communication). Details of measurement of environmental parameters and their relationships are discussed elsewhere (Lynts, 1966a). It was believed that the stations should be reoccupied under as different environmental conditions as possible to act as a control on earlier collections. Stations were therefore resampled on February 9th, 1963. A total of 74 samples were collected.

These samples were treated with rose Bengal, following the procedure described by Walton (1952). Counts of a maximum of 300 stained specimens were made from the 14th and 17th of August 1962 collections, to estimate the standing crop, while all of the stained specimens in the top centimeter of cores were counted from the August 20th, 1962 and February 9th, 1963 collections. Percentages of standing crop values for each collection are given in Tables 1, 2, 3 and 4.

Shenton (1957) and Lynts (1962) have quantitatively investigated the relationship between foraminiferal-sediment size distributions and indicated that the sediment size might be an ecologic factor influencing the distribution of some species. Bandy (1963, personal communication) indicated that some foraminiferal species could be used to predict size of sediment in which they occur. The values for the percent of sand ($\geq 74\mu$), silt and clay are given in Tables 1, 2, 3 and 4.

The above data were analyzed quantitatively to determine the ecological influence upon the distribution of Foraminifera. Linear relationships between foraminiferal species and ecological parameters were analyzed by means of a factor-vector program (Imbrie, 1963; Manson and Imbrie, 1964). This program has been used to analyze foraminiferal faunas of the northwestern Great Bahama Bank (Streeter, 1963, 1964a) and Orinoco-Trinidad-Paria Shelf (Streeter, 1964b).

ENVIRONMENTAL REALM

Florida Bay is a shallow, triangular-shaped body of water containing many low mangrove keys. The Everglades swamps and the mangrove keys, along with turtle grass (Thalassia testudinum Konig), supply many organic nutrients. It is an area of active organically derived carbonate deposition: (Baars, 1963; Gorsline, 1963; Taft and Harbaugh, 1964; Ginsburg, 1964), divided into a series of shoals and basins. Shoals regions consist of fine grained sediments which have been trapped by Thalassia testudinum, while the basins contain mainly shell gravels. The environment of the bay is characterized by its shallow depth, low tides and widely fluctuating physiochemical parameters (Ginsburg, 1956, 1964; Lloyd, 1964; Taft and Harbaugh, 1964).

Buttonwood Sound

Oceanography. Buttonwood Sound is a restricted portion of Florida Bay adjacent to Largo Key (Fig. 1). It is bounded by mangrove keys on the northeast and southwest, and opens to Florida Bay in the northwest. It is shallow, with a maximum depth of approximately 2.7 meters (Fig. 2).

Little information has been published on the hydrography of the sound. Lloyd (1964) has measured salinities and oxygen isotope ratios from two stations during August 1958, and January 1959 reporting values of 36.5‰ and 2.3, and 31.7‰ and 1.9, respectively.

The salinity and pH of the water column were measured at each collecting station during the February 9th, 1963 effort. The water column at each station showed a uniform salinity and pH of 39.6‰ and 8.2, respectively.

Sediments. Each sample was analyzed for percent sand ($\geq 74\mu$), silt and clay. The ratios are given in Tables 1, 2, 3 and 4. The variations between collections at each station are the result of the inability to reoccupy each station exactly. The ratios from the four collections have been used to prepare a sediment size distribution map (Fig. 3). Details of how this map was prepared have been discussed elsewhere (Lynts, 1966a).

Finer sediments were restricted to regions of Thalassia testudium, which effectively traps them (Ginsburg and Lowenstam, 1958). The sediment at station 12 (Fig. 1) had been thoroughly reworked, as indicated by an abundance of fecal pellets similar to those attributed to holothuroids by Baars (1963). An area of coarser sediment was found adjacent to Largo Key (Fig. 3).

Composition of the sediments was almost wholly carbonate, presumably derived from organic activity. Most of the finer fraction consisted of triturated remains of shells and tests. Clay minerals made up a very minor part of the clay grade-size (Gorsline, 1963). The fine fraction had a high organic content, a result of the breakdown of mangrove and turtle grass debris. This organic matter was not rapidly removed from the sediments by microbial action because of the strongly reducing environment of the sediments. The coarser fraction consisted mainly of molluscan debris, with foraminiferal tests adding significantly to this size grade. Remains of other organisms: ostracodes, echinoids, bryozoans, sponge spicules, ophuiroids and alcyonarians; and a small number of quartz grains, made up the remainder of the fraction.

The environmental parameters of the water-sediment interface did not coincide with those of the overlying waters because of a lag in adjustment between the two phases (Oppenheimer, 1963, personal communication). The only reliable Eh potentials were from the February 1963 collection as the August 1962 measurements were taken after disturbing the water-sediment interface (Lynts, 1966a). Redox potentials of the August 1962 collections may be higher than in situ values, but not any lower (Oppenheimer, 1963, personal communication). Although little information on Eh potentials from carbonate sediments was available (Baas Becking, et al., 1960), the February 1963 redox potentials coincided quite well with the few other measurements taken in Florida Bay (Lindblom and Lupton, 1961).

FAUNAL ANALYSIS

Buttonwood Sound has a maximum depth of approximately 2.7 meters (Fig. 2) and therefore lies within the porcelaneous foraminiferal zone (Phleger, 1960). This is substantiated by the fact that 92 percent of the standing crop was composed of porcelaneous species. A significant part of the fauna is made up of perforate and agglutinate species, five and three percent, respectively. The most abundant porcelaneous species are:

Quinqueloculina bosciana d'Orbigny

Triloculina bermudezi Acosta

Quinqueloculina poeyana d'Orbigny

Quinqueloculina laevigata d'Orbigny

Hauerina bradyi Cushman

while the most common perforate species are Ammonia translucens (Phleger and Parker) and Rosalina floridana Cushman; the most abundant agglutinate species are Valvulina oviedoiana d'Orbigny and Schenckiella occidentalis (Cushman).

August 14th, 1962 Collection

The standing crop was dominated by porcelaneous species (91%), but there were significant numbers of perforate and agglutinate species (6 and 3% respectively). The most common species was Triloculina bermudezi (Table 1), which was found at every station and made up 20 percent of the fauna, while dominant perforate and agglutinate forms were Ammonia translucens and Schenckiella occidentalis, occurring at six and nine stations, respectively, and each making up two percent of the population.

The standing crop was analyzed in terms of a simple, linear mathematical model known as factor-vector analysis (Imbrie, 1963; Manson and Imbrie, 1964; Imbrie and Van Andel, 1964; Gould, 1967). This procedure resolves each sample into contributions from a small number of reference, or end-member, samples. The objective of this analysis is to account for a large fraction of the total information* in the collection in terms of a simple causal scheme.

* The sum of squares of all entries in data table is defined as total information.

Considering the August 14th, 1962 collection, the Q-modal analysis yielded five reference samples (faunal assemblages) (Table 6a, Figs. 4a-e) which together accounted for 93 percent of the total information.

Using the same approach, the ecologic parameters (depth, temperatures, salinity, pH, Eh and sediment size) were investigated. The result, Environmental Model I (Table 6b, Fig. 5), accounts for 95 percent of the total information.

Environmental Model I is an attempt to integrate available information on environmental parameters and to display systematic patterns of geographic variations in the physical portion of the ecosystem. Admittedly, the number of available parameters is few, but this model does, on an objective and reproducible basis, reveal significant geographic patterns. By comparing the assemblage maps, in this instance, the analysis reveals that much of the variance is closely interlocked, so that only one dimension of environmental change is shown. In the study of other environments, however, where more parameters are measured or where more complex systems occur, it can be anticipated that more than one dimension will be revealed.

Assemblage I (Fig. 4a) is characterized by a dominance of Triloculina bermudezi and the rarer occurrence of Discorbis mira, Rosalina floridana and Clavulina tricarinata d'Orbigny. Though the relationship is not strong, it appears to be inversely related to Environmental Model I (Fig. 5).

Assemblage II (Fig. 4b) is dominated by Quinqueloculina poeyana. Discorbis mira and Schenckiella occidentalis are the most common perforate and agglutinate species, respectively. This assemblage is restricted to the southern and southeastern parts of the sound and appears to be inversely related to both depth (Fig. 2) and salinity (Table 1).

Assemblage III (Fig. 4c) is characterized by the dominance of Archaias angulatus (Fichtel and Moll) and rarer occurrences of Elphidium galvestonense Kornfeld and Valvulina oviedoiana (group 1). This assemblage is located adjacent to Largo Key and appears to be directly related to the coarser sediments (clayey sand) found there (Fig. 3).

Assemblage IV (Fig. 4d) is dominated by Triloculina bermudezi. Rosalina floridana is the most abundant perforate species, while Schenckiella occidentalis and Ammodiscus incertus (d'Orbigny) are the most common agglutinate forms. It is distinguished from Assemblage I by lack of abundant Discorbis mira and the presence of Ammodiscus incertus. This assemblage is restricted to the central portion of the sound and though the relationship is not strong, appears to be directly related to depth of water (Fig. 2).

Assemblage V (Fig. 4e) is characterized by a dominance of Quinqueloculina bosciana and the rarer occurrence of Rosalina floridana. The pattern of the assemblage does not fit any of the measured environmental information well, but may indicate current influence.

The linear relationship between distribution of foraminiferal species and environmental parameters was investigated using factor-vector R-modal analysis. As would be expected, the analysis indicated that the species most sensitive to changes in ecology are rarer forms. Species having similar linear ecological adaptations are grouped together. These reaction groups cut across taxonomic lines, for example the following species are indicated to have similar ecological adaptations:

Cribroelphidium poeyanum (d'Orbigny)

Planorbulina mediterranensis d'Orbigny

Elphidium advenus (Cushman)

Pyrgo subsphaerica (d'Orbigny)

Triloculina sidebottomi (Martinotti)

Bolivina lanceolata Parker

The analysis indicates that the distributions of some species appear to be linearly related to the environmental parameters which were measured. The distribution of Cribroelphidium poeyanum is inversely related to temperature. Distribution of Clavulina tricarinata is directly related to the ratio of clay and inversely related to pH and depth. Distributions of Elphidium galvestonense, Massilina secans (d'Orbigny) and Ammonia beccarii (Linnaeus) are directly related to ratio of sand. Distribution of Quinqueloculina bosciana is inversely related to salinity. These relationships are not particularly strong and probably do not control distributions, but only partially influence them.

August 17th, 1962 Collection

Porcelaneous species made up 91 percent of the standing crop, while perforate and agglutinate forms made up five and four percent, respectively. The dominant species was Triloculina bermudezi (Table 2) which occurred at 18 of the 19 stations and made up 20 percent of the fauna. Rosalina floridana occurred at 12 stations, making up two percent of the population, while Schenckiella occidentalis occurred at nine stations and made up two percent of the fauna. These two species were the most common perforate and agglutinate forms, respectively.

Q-modal factor-vector analysis of the standing crop yielded five faunal assemblages (Table 7a, Figs. 6a-e). These account for 96 percent of the total information. Distribution of environmental parameters was also analyzed and resulted in Environmental Model II (Table 7b, Fig. 7) which account for 98 percent of the total information.

Assemblage VI (Fig. 6a) is dominated by Triloculina bermudezi. Rosalina floridana and Schenckiella occidentalis are the most important perforate and agglutinate species, respectively. This model does not fit any of the available environmental information.

Assemblage VII (Fig. 6b) is characterized by the dominance of Quinqueloculina poeyana and the rarer occurrence of Rosalina floridana. This faunal assemblage appears to be inversely related to both Environmental Model II (Fig. 7) and depth (Fig. 2).

Assemblage VIII (Fig. 6c) is dominated by Quinqueloculina bosciana. Rosalina floridana is the most abundant perforate species. This faunal assemblage does not fit any measured environmental information. Its pattern suggests a possible partial current influence.

Assemblage IX (Fig. 6d) is characterized by dominance of Hauerina bradyi and rarer occurrence of Rosalina floridana. This assemblage is restricted to the central part of the sound and appears to be directly related to water depth (Fig. 2).

Assemblage X (Fig. 6e) is dominated by Quinqueloculina subpoeyana Cushman. Elphidium galvestonense and Valvulina oviedoiana group 1 are the most common perforate and agglutinate species, respectively. This assemblage occurs adjacent to Largo Key where coarser sediments (clayey sand) are found and appears to be directly related to sediment size (Fig. 3).

Linear relationships between distribution of foraminiferal species and environmental parameters were investigated using R-modal factor-vector analysis. The following linear relationships were indicated: Distribution of Quinqueloculina subpoeyana is directly related to ratio of sand. Distributions of Quinqueloculina laevigata and Quinqueloculina bosciana are directly related to temperature. These relationships are not extremely strong and probably do not control distributions, but only partially influence them. The distribution of Schenckiella occidentalis shows a strong direct relationship to salinity. Clavulina tricarinata and Discorbis mira distributions are inversely related to depth.

August 20th, 1962 Collection

This fauna was dominated by porcelaneous species (92%), but had significant numbers of perforate and agglutinate forms (5 and 3%, respectively). Quinqueloculina bosciana and Quinqueloculina poeyana (Table 3) were the most common species, both occurring at 18 of 19 stations and each making up 14 percent of the standing crop. Dominant perforate species were

Discorbis mira and Rosalina floridana, which occurred at ten and nine stations, respectively, each making up one percent of the fauna. Schenckiella occidentalis occurred at 11 stations, composing one percent of the fauna, and was the most abundant agglutinate form.

Q-modal factor-vector analysis of the standing crop yielded four reference samples (Table 8a, Figs. 8a-d) that accounted for 89 percent of the total information. Environmental parameters were similarly analyzed, yielding Environmental Model III (Table 8b, Fig. 9), which accounted for 98 percent of the total information.

Assemblage XI (Fig. 8a) is characterized by dominance of Quinqueloculina bosciana and rarer occurrence of Schenckiella occidentalis, Discorbis mira and Rosalina floridana. This assemblage appears to be directly related to temperature (Table 3).

Assemblage XII (Fig. 8b) is dominated by Hauerina bradyi. Elphidium glavestonense and Rosalina floridana are the most common perforate species. This faunal assemblage appears to be directly related to depth of water (Fig. 2). Its pattern indicates that it is probably also partially influenced by currents.

Assemblage XIII (Fig. 8c) is characterized by dominance of Quinqueloculina bosciana and rarer occurrence of Schenckiella occidentalis and Discorbis mira. It is distinguished from Assemblage XI by lack of abundant Rosalina floridana. Though the relationship is not strong, it appears to be directly related to Environmental Model III (Fig. 9).

Assemblage XIV (Fig. 8d) is dominated by Quinqueloculina poeyana. Discorbis mira and Schenckiella occidentalis are the most important perforate and agglutinate forms, respectively. This faunal assemblage appears to be inversely related to Environmental Model III (Fig. 9).

R-modal factor-vector analysis indicated that the distributions of Clavulina tricarinata and Discorbis mira are inversely related to water depth. These relationships are not particularly strong and this parameter probably does not control distribution, but only partially influences it.

February 9th, 1963 Collection

The standing crop from this collection was dominated by porcelaneous species, which made up 93 percent of the fauna. Significant numbers of perforate and agglutinate forms did occur, making up four and three percent of the population, respectively. The porcelaneous forms Quinqueloculina laevigata, which occurred at 16 of 17 stations and made up 24 percent of the standing crop, and Quinqueloculina bosciana, which occurred at all 17 stations and made up 23 percent of the population, were the most abundant species in the collection (Table 4). The most common agglutinate form was Valvulina oviedoiana (group 1) which occurred at five stations and made up two percent of the standing crop. None of the perforate species were important constituents of the fauna.

Q-modal factor-vector analysis of the standing crop yielded three faunal assemblages (Table 9a, Figs. 10a-c), accounting for 83 percent of the total information. The environmental parameters were investigated in a similar manner and yielded Environmental Model IV (Table 9b, Fig. 11), which accounted for 99 percent of the total information.

Assemblage XV (Fig. 10a) is dominated by Quinqueloculina bosciana. Discorbis mira is the most important perforate species. This assemblage does not fit any of the available environmental information and therefore is probably not influenced by the measured environmental parameters.

Assemblage XVI (Fig. 10b) is characterized by dominance of Quinqueloculina laevigata and rarer occurrence of Rosalina floridana and Discorbis mira. This faunal assemblage appears to be inversely related to sediment size (Fig. 3).

Assemblage XVII (Fig. 10c) is dominated by Hauerina bradyi. It is found in the northeastern and central parts of the sound and does not fit any of the measured environmental information.

R-modal factor-vector analysis was used to investigate linear relationships between distribution of foraminiferal species and environmental parameters. It indicates that Quinqueloculina seminulum and Quinqueloculina poeyana distributions are inversely related to ratio of silt. Distribution of Archaias angulatus is inversely related to salinity. These relationships are not strong and therefore probably do not control distributions, but only partially influence them.

Ecological Relationships Among Species

All of the foraminiferal faunal and environmental data from the four collections were used in an attempt to define those ecological parameters which control or partially influence species distributions in Buttonwood Sound.

R-modal factor-vector analysis indicated that species distributions were not strongly related to depth, temperature, salinity, pH, Eh or ratios of sand, silt or clay. It did indicate that some species had similar ecological adaptations. The following three groups of species were obtained:

Rosalina floridana Cushman
Conorbina orbicularis (Williamson)

Quinqueloculina agglutinans d'Orbigny
Triloculina bassensis Parr
Archaias agnulatus (Fichtel and Moll)

Quinqueloculina poeyana d'Orbigny
Miliolinella obliquinoda (Riccio)
Quinqueloculina bosciana d'Orbigny

The species within each group have similar ecological adaptations, but what these adaptations are is not evident.

Variations Between Collections

Inspection of Tables 1-4 indicates there are differences in faunal composition at some stations between collections. Statistical analysis indicates these variations are significant.

Previously, it had been mentioned it was not possible to reoccupy stations exactly. Samples at each station were probably collected within a three meter radius. It does not appear that the measured environmental parameters varied enough between the August 1962 collections to cuase significant changes in faunal composition. It is believed hhat faunal differences which are observed between these collections result from variation of foraminiferal standing crop over short lateral distances (Lynts, 1966b).

Differences in faunal composition at some stations between the August 1962 collections and February 1963 collection are probably the result of variation of environmental parameters between these two times of the year (Table 5). Significant variation in faunal composition does not occur at every station indicating that many foraminiferal species are tolerant to changes in their environment of these magnitudes.

Summary

The foraminiferal standing crop of Buttonwood Sound is dominated by porcelaneous species, 92 percent, but there are significant numbers of perforate and agglutinate forms, five and three percent, respectively. There were minor fluctuations in these percents between collections, but the relative compositions did not vary.

Each collection was subdivided into faunal assemblages. Five of the faunal assemblages (V, VI, VIII, XV, XVII) do not appear to be linearly related to any of the measured environmental data, but the pattern of two of these assemblages (V, VIII) does indicate a probable current influence. Four of the assemblages (K, VII, XIII, XIV) appear to be linearly related to the environmental models (I, II, III).

Four faunal assemblages (II, IV, IX, XII) appear to be linearly related to bathymetry. A fauna which persists throughout all four collections is related to bathymetry. It consists of Assemblages IV and IX, and other assemblages that occur in both the August 20th, 1962 and February 9th, 1963 collections but which are not illustrated because they did not account for enough total information in their respective collections. Two of the assemblages which are related to depth (II, XII) also appear to be partially influenced by other factors. Distribution of Assemblage II appears to be related to both depth and salinity, while Assemblage XII appears to be related to depth and currents.

Three assemblages (III, X, XVI) appear to be linearly related to sediment size. A fauna related to sediment size persists throughout all of the collections. Faunal Assemblages III and X are part of this fauna, as are assemblages from the August 20th, 1962 and February 9th, 1963 collections. The assemblages from these latter two collections are not illustrated because they did not answer enough total information.

A single faunal assemblage (XI) related to temperature was also defined.

Ecological relationships of the faunal assemblages suggest that most assemblage distributions are controlled by interaction of ecological parameters, including physicochemical and biologic factors which were not measured.

Linear relationship between distribution of foraminiferal species and environmental parameters was also investigated. Each of the four collections was analyzed, and the distribution of several species appears to be linearly related to measured environmental parameters. These relationships are not extremely strong, in most cases, and probably do not control distribution, but only partially influence it. Analysis utilizing data from all of the collections indicated that some foraminiferal species have similar ecological adaptations. Exactly what ecological adaptation the Foraminifera had in common was not evident, because no linear relationships were defined. This again suggests that the distribution is probably controlled by interaction of physicochemical and biologic factors.

CONCLUSIONS

1. The ecology of Buttonwood Sound fluctuates considerably from summer to winter.

2. The foraminiferal fauna is dominated by porcelaneous species, but there are significant numbers of perforate and agglutinate forms. Q-modal factor-vector analysis divided the standing crop of each collection into faunal assemblages. Most of the distributions of these assemblages are controlled by interacting physicochemical and biologic factors.

3. Investigation of linear relationships between distribution of foraminiferal species and environmental parameters for each collection indicates some species are influenced by the measured environmental parameters. Most species showed no such relationship. Analysis of all collections combined indicates that some species have similar ecological adaptations, but exactly how these ecological adaptations affect the Foraminifera is not evident. Species least tolerant to changes in their ecology were the rarer forms.

4. No simple linear relationship exists between Buttonwood Sound foraminiferal species and ecological distributions. The distribution of species is controlled by a complex interplay of physicochemical and biologic factors acting upon the species.

DISCUSSION OF SPECIES

In the following discussion, terms will be used as herein defined: 1) Collection means specimens collected on a certain date, for example, the August 14th, 1962 collection; 2) All Collections include those specimens collected on August 14th, 17th, 20th, 1962, and February 9th, 1963; 3) Fauna consists of specimens of all collections; and 4) Standing crop and Population consist of specimens from a collection.

ORDER FORAMINIFERIDA Eichwald, 1830

SUBORDER TEXTULARINA Delage and Herouard, 1896

SUPERFAMILY AMMODISCACEA Reuss, 1862

FAMILY AMMODISCIDAE Reuss, 1862

SUBFAMILY AMMODISCINAE Reuss, 1862

GENUS *AMMODISCUS* Reuss, 1862

Ammodiscus incertus (d'Orbigny), 1839+

+ Loeblich and Tappan (1954) examined d'Orbigny's types of Operculina incerta from Cuba and figured a lectotype. They placed the species in Cornuspira which is a junior synonym of Cyclogyra. The specimens probably should be reffed to Ammodiscus anguillae Höglund.

Operculina incerta d'Orbigny, 1839, in De la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminiferes", p. 49, Pl. 6, Figs. 16, 17.

This species occurred in all collections but the August 20th, 1962. It was very rare, with frequencies of less than one percent.

GENUS GLOMOSPIRA Rzehak, 1885

Glomospira charoides (Jones and Parker), 1862

Trochammina charoides Jones and Parker, 1862, in Carpenter, Parker and Jones, Introd. Foram., p. 141, Pl. 11, Fig. 3.

This species occurred in all collections. It was quite rare, with frequencies of less than one percent at all but two stations. It occurred in frequencies of four and one percent at two stations, 5 and 7, of the August 20th, 1962 collection.

SUPERFAMILY LITUOLACEA de Blainville, 1825

FAMILY LITUOLIDAE de Blainville, 1825

SUBFAMILY LITUOLINAE de Blainville, 1825

GENUS AMMOBACULITES Cushman, 1910

Ammobaculites dilatatus Cushman and Bronnimann, 1948

Ammobaculites dilatatus Cushman and Bronnimann, 1948, Contr. Cushman Lab. Foram. Res., vol. 24, p. 39, Pl. 7, Figs. 10, 11.

Specimens of this species showed considerable variation in chamber inflation. There was gradation from deflated specimens (Plate 1, Fig. 3) to inflated specimens (Plate 1, Fig. 4). Quite possibly if only deflated specimens were found they would be placed in the genus Ammoscalaria Höglund.

This species occurred in all collections except February 9th, 1963. It was quite rare, with frequencies of less than one percent at all but two stations. It occurred with a frequency of one percent at station 1 of the August 14th, 1962 collection and two percent at station 3 of the August 20th, 1962 collection.

Ammobaculites exiguus Cushman and Bronnimann, 1948

Ammobaculites exiguus Cushman and Bronnimann, 1948, Contr. Cushman Lab. Foram. Res., vol. 24, p. 38, Pl. 7, Figs. 7, 8.

This species occurred as a single specimen at station 1 of the August 20th, 1962 collection. Dead specimens occurred in the total population at most stations.

FAMILY ATAXOPHRAGMIIDAE Schwager, 1887

SUBFAMILY VALVULININAE Berthelin, 1880

GENUS VALVULINA d'Orbigny, 1826

Valvulina oviedoiana d'Orbigny, 1839

Valvulina oviedoiana d'Orbigny, 1839, in De la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminiferes", p. 103, Pl. 2, Figs. 21, 22.

This species was divided into two groups based upon presence (group 1) or absence (group 2) of valvular flap over the aperture (Lynts, 1965). Group 1 was the dominant form making up 81 percent of the specimens of this species.

This was the most abundant agglutinate form. It occurred in all collections. It had a maximum frequency of 27 percent at station 1 of the February 9th, 1963 collection.

GENUS CLAVULINA d'Orbigny, 1826

Clavulina tricarinata d'Orbigny, 1839

Clavulina tricarinata d'Orbigny, 1839, in De la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminiferes", p. 111, Pl. 2, Figs. 16-18.

This species occurred in all collections. It had a maximum frequency of nine percent at station 4 of the August 20th, 1962 collection. Its distribution was inversely related (r = -0.584) to pH and directly related (r = +0.540) to clay-size sediment in the August 14th, 1962 collection. The correlation coefficients were significant, but not numerically high so the importance of these parameters to its distribution was not clear. Its distribution was inversely related to depth in the August 1962 collections (r = -0.550, -0.821 and -0.664, respectively). It appears, because this relationship was fairly strong and consistent in the August 1962 collections, that it probably prefers shallower water.

GENUS SCHENCKIELLA Thalman, 1942*

---

* Loeblich and Tappan (1964) indicated Schenckiella is a junior synonym of Martinottiella Cushman, 1933.

Schenckiella occidentalis (Cushman), 1922

Clavulina occidentalis Cushman, 1922, U.S. Nat. Mus. Bull. 104, pt. 3, p. 87, Pl. 17, Figs. 1, 2.

This species was the most abundant agglutinate form in the August 14th and 17th, 1962 collections. It occurred in all collections with a frequency up to 11 percent at station 17 of the August 17th, 1962 collection. In the August 17th, 1962 collection, its distribution appeared to have been directly related, quite strongly (r = +0.812), to temperature.

SUBORDER MILIOLINA Delage and Herouard, 1896

SUPERFAMILY MILIOLACEA Ehrenberg, 1839

FAMILY FISCHERINIDAE Millet, 1898

SUBFAMILY CYCLOGYRINAE Loeblich and Tappan, 1961

GENUS CYCLOGYRA Wood, 1842

Cyclogyra involvens (Reuss), 1850

Operculina involvens Reuss, 1850, Denschr. Akad. Wiss. Wien, vol. 1, p. 370, Pl. 46, Fig. 30.

This species occurred in all collections. It was fairly rare, with a maximum frequency of six percent at station 7 of the August 14th, 1962 collection.

FAMILY NUBECULARIIDAE Jones, 1875

SUBFAMILY SPIROLOCULININAE Wiesner, 1920

GENUS SPIROLOCULINA d'Orbigny, 1826

Spiroloculina antillarum d'Orbigny, 1839

Spiroloculina antillarum d'Orbigny, 1839, in de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminiferes", p. 166, Pl. 9, Figs. 3, 4.

This species occurred in all collections but the August 20th, 1962. It was very rare, occurring in frequencies of less than one percent.

Spiroloculina eximia Cushman, 1922

Spiroloculina eximia Cushman, 1922, Carnegie Inst. Washington Publ., no. 311, p. 61, Pl. 11, Fig. 2.

This species occurred in the August 14th and 17th, 1962 collection. Only two specimens were found. One occurred at station 5 of the August 14th, 1962 collection and one at station 1 of the August 17th, 1962 collection.

SUBFAMILY NODOBACULARIINAE Cushman, 1927

GENUS NODOBACULARIELLA Cushman and Hanzawa, 1937

Nodobaculariella cassis (d'Orbigny), 1839

Vertebralina cassis d'Orbigny, 1839, in de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminiferes", p. 51, Pl. 7, Figs. 14, 15.

This species occurred as a single specimen at station 6 of the August 20th, 1962 collection.

FAMILY MILIOIDAE Ehrenberg, 1839

SUBFAMILY QUINQUELOCULININAE Cushman, 1917

GENUS QUINQUELOCULINA d'Orbigny, 1826

Quinqueloculina agglutinans d'Orbigny, 1839

Quinqueloculina agglutinans d'Orbigny, 1839, in de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminiferes", p. 195, Pl. 12, Figs. 11-13.

This species occurred in all collections. It was most abundant in the August 14th, 1962 collection when it had a maximum frequency of eight percent at station 2.

Quinqueloculina bosciana d'Orbigny, 1839

Quinqueloculina bosciana d'Orbigny, 1839, in de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminiferes", p. 191, Pl. 11, Figs. 22-24.

This species was the predominant form in the fauna. It occurred in all collections and made up 17 percent of the fauna. It was most important in the February 9th, 1963 collection when it made up 23 percent of the standing crop. It had a maximum frequency of 100 percent at station 9 of the August 17th, 1962 collection. Its distribution was inversely related (r = -0.532) to salinity in the August 14th, 1962 collection and directly related (r = +0.510) to temperature in the August 17th, 1962 collection. The correlation coefficients were significant, but not numerically high so the importance of these parameters to its distribution was not clear.

Quinqueloculina laevigata d'Orbigny, 1826

Quinqueloculina laevigata d'Orbigny, 1826, Ann. Sci. Nat., vol. 7, p. 301, No. 6.

This species occurred in all collections. It was fairly common, making up 12 percent of the fauna. It was most abundant in the February 9th, 1963 collection when it made up 24 percent of the standing crop. It had a maximum frequency of 89 percent at station 9 of the February 9th, 1963 collection. Its distribution was directly related (r = +0.544) to temperature in the August 17th, 1962 collection. The correlation coefficient was significant, but not numerically high so the importance of this parameter to its distribution was not clear.

Quinqueloculina lamarckiana d'Orbigny, 1839

Quinqueloculina lamarckiana d'Orbigny, 1839, *in* de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminiferes", p. 189, Pl. 11, Figs. 14, 15.

This species occurred in all collections. It was fairly rare, with a maximum frequency of eight percent at station 2 of the August 14th, 1962 collection.

Quinqueloculina poeyana d'Orbigny, 1839

Quinqueloculina poeyana d'Orbigny, 1839, *in* de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminiferes", p. 191, Pl. 11, Figs. 25-27.

This species occurred in all collections. It was fairly common, making up 12 percent of the fauna. It was most abundant in the August 20th, 1962 collection when it made up 14 percent of the standing crop and had a maximum frequency of 36 percent at station 10. Its distribution was inversely related (r = -0.546) to the ratio of silt-size sediment in the February 9th, 1963 collection. The correlation coefficient was significant, but not numerically high so the importance of this parameter to its distribution was not clear.

Quinqueloculina polygona d'Orbigny, 1839

Quinqueloculina polygona d'Orbigny, 1839, *in* de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminiferes", p. 198, Pl, 12, Figs. 21-23.

This species occurred in all collections. It was quite rare, with a maximum frequency of three percent at station 15 of the August 17th, 1962 collection.

Quinqueloculina sabulosa Cushman, 1947

Quinqueloculina sabulosa Cushman, 1947, Contr. Cushman Lab. Foram. Res., vol. 23, p. 87, Pl. 18, Fig. 22.

Specimens were generally larger in the February 9th, 1963 collection than in the August 1962 collections.

This species occurred in all collections. It was fairly rare, making up two percent of the fauna. It had a maximum frequency of 43 percent at station 8 of the August 20th, 1962 collection.

Quinqueloculina seminulum (Linnaeus), 1758

Serpula seminulum Linnaeus, 1758, Syst. Nat., ed. 10, p. 786.

This species occurred in all collections. It was fairly rare, making up two percent of the fauna. It had a maximum frequency of eight percent at station 18 of the August 14th, 1962 collection. Its distribution was inversely related (r = -0.572) to the ratio of silt-size sediment in the February 9th, 1963 collection. The correlation coefficient was significant, but not numerically high so the importance of the parameter to its distribution was not clear.

Quinqueloculina subpoeyana Cushman, 1922

Quinqueloculina subpoeyana Cushman, 1922, Carnegie Inst. Washington Publ., no. 311, p. 66.

This species occurred in all collections, being most important in the February 9th, 1963 collection when it made up six percent of the standing crop. It was fairly rare, making up three percent of the fauna. It had a maximum frequency of 28 percent at station 2 of the February 9th, 1963 collection. Its distribution was directly related (r = +0.677) to the ratio of sand-size sediment in the August 17th, 1962 collection. The correlation coefficient was highly significant, but not numerically high so the importance of this parameter to its distribution was not clear.

Quinqueloculina tenagos Parker, 1962

Quinqueloculina costata d'Orbigny (nomen nudum, fide Parker, 1953), 1826, Ann. Sci. Nat., vol. 7, p. 301, No. 3.

Quinqueloculina rhodiensis Parker, 1953, in Parker, Phleger, Peirson, Cushman Found. Foram. Res., Spec. Publ. No. 2, p. 12, Pl. 2, Figs. 15-17; Lynts, 1962, Contr. Cushman Found. Foram. Res., vol. 13, p. 141.

Quinqueloculina tenagos Parker, 1962, Contr. Cushman Found. Foram. Res., vol. 13, p. 110.

This species occurred in all collections. It was quite rare, never occurring in frequencies greater than one percent.

GENUS MASSILINA Schlumberger, 1893

Massilina secans (d'Orbigny), 1826

Quinqueloculina secans d'Orbigny, 1826, Ann. Sci. Nat., vol. 7, p. 303, No. 43.

This species occurred in all collections. It was quite rare, with a maximum frequency of four percent at station 17 of the February 9th, 1963 collection. It was directly related (r = +0.598) to the ratio of sand-size sediment in the August 14th, 1962 collection. The correlation coefficient was highly significant, but not numerically high so the importance of this parameter to its distribution was not clear.

GENUS PYRGO Defrance, 1824

Pyrgo subsphaerica (d'Orbigny), 1839

Biloculina subsphaerica d'Orbigny, 1839, in de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminiferes", p. 162, Pl. 8, Figs. 25-27.

This species occurred as a single specimen at station 1 of the August 14th, 1962 collection.

GENUS TRILOCULINA d'Orbigny, 1826

Triloculina bassensis Parr, 1945

Triloculina bassensis Parr, 1945, Roy. Soc. Victoria Proc., vol. 56, (n. ser.), p. 198, Pl. 8, Figs. 7a-c.

This species occurred in all collections. It was fairly rare, with a maximum frequency of 13 percent at station 2 of the August 14th, 1962 collection.

Triloculina bermudezi Acosta, 1940

Triloculina bermudezi Acosta, 1940, Soc. Cuba Hist. Nat., Mem., vol. 14, no. 1, p. 37, Pl. 4, Figs. 1-5.

This species was one of the most common forms, making up 15 percent of the fauna. It was the predominant species in the August 14th and 17th, 1962 collections making up 20 percent of the standing crop in each collection. It had a maximum frequency of 43 percent at two stations, 5 and 7, of the August 14th, 1962 collection.

Triloculina linneiana d'Orbigny, 1839

Triloculina linneiana d'Orbigny, 1839, in de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminiferes", p. 172, Pl. 9, Figs. 11-13.

This species occurred in all collections. It was fairly rare, making up three percent of the fauna. Its maximum frequency was 11 percent at station 10 of the August 14th, 1962 collection.

Triloculina oblonga (Montagu), 1803

Vermiculum oblonga Montagu, 1803, Test. Brit., p. 522, Pl. 14, Fig. 9.

This species occurred in all collections. It was fairly rare, with a maximum frequency of 17 percent at station 13 of the August 17th, 1962 collection.

Triloculina rotunda d'Orbigny, 1826

Triloculina rotunda d'Orbigny, 1826, Ann. Sci. Nat., vol. 7, p. 299, No. 4.

This species occurred in all collections. It was fairly rare, with a maximum frequency of six percent at station 5 of the August 17th, 1962 collection.

Triloculina sidebottomi (Martinotti), 1920

Sigmoilina sidebottomi Martinotti, 1920, Atti. Soc. Ital. Sci. Nat., vol. 59, p. 280, Pl. 2, Fig. 29, Text Figs. 59-61.

This species occurred in the August 14th and 20th, 1962 collections. Only four specimens were found. Three occurred at station 1 of the August 14th, 1962 collection and one at station 2 of the August 20th, 1962 collection.

Triloculina trigonula (Lamarck), 1804

Miliola trigonula Lamarck, 1804, Ann. Mus., vol. 5, p. 351, No. 3.

This species occurred in all collections. It was quite rare, with a maximum frequency of five percent at station 14 of the August 20th, 1962 collection.

SUBFAMILY MILIOLINELLINAE Vella, 1957

GENUS MILIOLINELLA Wiesner, 1931

Miliolinella circularis (Bornemann), 1855

Triloculina circularis Bornemann, 1855, Zeitschr. deutsch. geol. Ges., vol. 7, pt. 2, p. 349, Pl. 19, Figs. 4a-c.

This species was fairly common, occurring in all collections. It made up six percent of the fauna. It was most important in the August 20th, 1962 collection when it made up 14 percent of the standing crop and had a maximum frequency of 31 percent at station 18.

Miliolinella fichteliana (d'Orbigny), 1839

Triloculina fichteliana d'Orbigny, 1839, *in* de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminiferes", p. 171, Pl. 9, Figs. 8-10.

This species occurred in only the August 14th and 20th, 1962 collections. It was very rare, with frequencies of less than one percent.

Miliolinella labiosa (d'Orbigny), 1839

Triloculina labiosa d'Orbigny, 1839, *in* de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminiferes", p. 178, Pl. 10, Figs. 12-14.

This species occurred in only the August 20th, 1962 and February 9th, 1963 collections. It was very rare, with frequencies of less than one percent.

Miliolinella obliquinoda (Riccio), 1950

Triloculinella obliquinoda Riccio, 1950, Contr. Cushman, Found. Foram. Res., vol. 1, p. 90, Pl. 15, Figs. 1, 2.

This species occurred in all collections. It was quite rare, with a maximum frequency of 16 percent at station 13 of the August 14th, 1962 collection.

Miliolinella suborbicularis (d'Orbigny), 1826

Triloculina suborbicularis d'Orbigny, 1826, Ann. Sci. Nat., vol. 7, p. 300, No. 12.

This species occurred as a single specimen at station 18 of the August 14th, 1962 collection.

SUBFAMILY MILIOLINAE Ehrenberg, 1839

GENUS HAUERINA d'Orbigny, 1839

Hauerina bradyi Cushman, 1917

Hauerina bradyi Cushman, 1917, U.S. Nat. Mus. Bull. 71, pt. 6, p. 62, Pl. 23, Fig. 2.

This species was fairly common, making up 11 percent of the fauna. It occurred in all collections. It was most abundant in the August 17th and 20th, 1962 collections when it made up 14 percent of the standing crop in each collection. Its maximum frequency was 76 percent at station 11 of the August 17th, 1962 collection.

FAMILY SORITIDAE Ehrenberg, 1839

SUBFAMILY ARCHAIASINAE Cushman, 1927

GENUS ARCHAIAS de Montfort, 1808

Archaias angulatus (Fichtel and Moll), 1803

Nautilus angulatus Fichtel and Moll, 1803, Test. Micr., p. 112, Pl. 21.

This species occurred in all collections. It was fairly rare, with a maximum frequency of 20 percent at station 2 of the August 14th, 1962 collection. Its distribution was inversely related (r = -0.594) to salinity in the February 9th, 1963 collection. The correlation coefficient was significant, but not numerically high so the importance of this parameter to its distribution was not clear.

SUBORDER ROTALIINA Delage and Herouard, 1896

SUPERFAMILY NODOSARIACEA Ehrenberg, 1838

FAMILY GLANDULINIDAE Reuss, 1860

SUBFAMILY OOLININAE Loeblich and Tappan, 1961

GENUS FISSURINA Reuss, 1850

Fissurina cf. F. lucida (Williamson), 1848

Entosolenia marginata Montagu, var. lucida Williamson, 1848, Ann. Mag. Nat. Hist., ser. 2, vol. 1, p. 17, Pl. 2, Fig. 17.

This species occurred in the August 20th, 1962 and February 9th, 1963 collections. It was very rare, with a maximum frequence of four percent at station 15 of the August 20th, 1962 collection.

SUPERFAMILY BULIMINACEA Jones, 1875

FAMILY TURRILINIDAE Cushman, 1927

SUBFAMILY TURRILININAE Cushman, 1927

GENUS BULIMINELLA Cushman, 1911

Buliminella elegantissima (d'Orbigny), 1839

Bulimina elegantissima d'Orbigny, 1839, Voy. Amer. Merid., vol. 5, pt. 5, "Foraminiferes", p. 51, Pl. 7, Figs. 13, 14.

This species occurred as a single specimen at station 2 of the February 9th, 1963 collection.

FAMILY BOLIVINITIDAE Cushman, 1927

GENUS BOLIVINA d'Orbigny, 1839

Bolivina lanceolata Parker, 1954

Bolivina lanceolata Parker, 1954, Mus. Compar. Zool., Bull., vol. 111, no. 10, p. 514, Pl. 7, Figs. 17-20.

This species occurred in all collections. It was very rare, with frequencies of less than one percent.

Bolivina lowmani Phleger and Parker, 1951

Bolivina lowmani Phleger and Parker, 1951, Geol. Soc. America, Mem., vol. 46, pt. 2, p. 13, Pl. 6, Figs. 20a, b, 21.

This species occurred as a single specimen at station 1 of the August 17th, 1962 collection.

Bolivina striatula Cushman, 1922

Bolivina striatula Cushman, 1922, Carnegie Inst. Washington Publ., no. 311, p. 27, Pl. 3, Fig. 10.

This species occurred as a single specimen at station 19 of the February 9th, 1963 collection.

SUPERFAMILY DISCORBACEA Ehrenberg, 1838

FAMILY DISCORBIDAE Ehrenberg, 1838

SUBFAMILY DISCORBINAE Ehrenberg, 1838

GENUS ROSALINA d'Orbigny, 1826

Rosalina floridana Cushman, 1922

Discorbis floridana Cushman, 1922, Carnegie Inst. Washington Publ., no. 311, p. 39, Pl. 5, Figs. 11, 12.

This was one of the most common perforate species, making up one percent of the fauna. It occurred in all collections. It was most common in the August 17th, 1962 collection when it made up two percent of the standing crop. It was quite rare, with a maximum frequency of seven percent at station 10 of the August 17th, 1962 collection.

GENUS CONORBINA Brotzen, 1936

Conorbina orbicularis, Williamson, 1858

Rotalina nitida Williamson (not Reuss), 1858, Rec. British Foram., p. 54, Pl. 4, Figs. 106-108.

This species occurred in all collections. It was very rare, with a maximum frequency of four percent at station 2 of the February 9th, 1963 collection.

Rosalina rosacea (d'Orbigny), 1826

Rotalia rosacea d'Orbigny, 1826, Ann. Sci. Nat., vol. 7, p. 273, No. 15.

This species occurred in all collections except the August 14th, 1962. It was very rare, with a maximum frequency of five percent at station 3 of the February 9th, 1963 collection.

SUPERFAMILY ROTALIACEA Ehrenberg, 1839

FAMILY ROTALIIDAE Ehrenberg, 1839

SUBFAMILY ROTALIINAE Ehrenberg, 1839

GENUS AMMONIA Brünnich, 1772

Ammonia beccarii (Linnaeus), 1758

Nautilus beccarii Linnaeus, 1758, Syst. Nat., ed. 10, p. 710, Pl. 1, Figs. 1a-c, Pl. 19, Figs. h, i.

This species occurred in all collections. It was most abundant in the August 14th, 1962 collection when it made up one percent of the standing crop. It was quite rare, with a maximum frequency of ten percent at station 16 of the August 14th, 1962 collection. Its distribution was directly related (r = +0.485) to the ratio of sand-size sediment in the August 14th, 1962 collection. The correlation coefficient was significant, but not numerically high so the importance of this parameter to its distribution was not clear.

GENUS DISCORBIS Lamarck, 1804

Discorbis mira (Phleger and Parker), 1951

"Rotalia" translucens Phleger and Parker, 1951, Geol. Soc. America, Mem., vol. 46, pt. 2, p. 24, Pl. 12, Figs. 11a, b, 12a, b.

This was the most common perforate species, making up one percent of the fauna. It occurred in all collections. It was most important in the August 14th, 1962 collection when it made up two percent of the standing crop. It was fairly rare, with a maximum frequency of 13 percent at station 5 of the August 20th, 1962 collection. Its distribution was inversely related (r = -0.870 and -0.728) to depth in the August 17th and 20th, 1962 collections, respectively. It appears, because of the quite strong relationship observed, that it probably prefers shallower water.

FAMILY ELPHIDIIDAE Galloway, 1933

SUBFAMILY ELPHIDIINAE Galloway, 1933

GENUS ELPHIDIUM de Montfort, 1808

Elphidium advenum (Cushman), 1922

Polystomella advena Cushman, 1922, Carnegie Inst. Washington Publ., no. 311, p. 56, Pl. 9, Figs. 11, 12.

This species occurred in the August 14th and 17th, 1962 collections. Only two specimens were found. One occurred at station 1 of the August 14th, 1962 collection and one at station 18 of the August 17th, 1962 collection.

Elphidium galvestonense Kornfeld, 1931

Elphidium gunteri Cole, var. galvestonense Kornfeld (part), 1931, Contr. Dept. Geol. Stanford Univ., vol. 1, no. 3, p. 87, Pl. 15, Figs. 1a, b (not 2a, b, 3a).

This species occurred in all collections. It was most abundant in the August 14th, 1962 collection when it made up one percent of the standing crop. It was quite rare, with a maximum frequency of nine percent at station 3 of the August 14th, 1962 collection. Its distribution was directly related (r = +0.610) to the ratio of sand-size sediment in the August 14th, 1962 collectin. The correlation coefficient was highly significant, but not numerically high so the importance of this parameter to its distribution was not clear.

GENUS CRIBROELPHIDIUM Cushman and Bronnimann, 1948

Cribroelphidium poeyanum (d'Orbigny), 1839*

---

* This species is equated to the genotype of Cribroelphidium Cushman and Bronnimann, 1948, by Loeblich and Tappan (1964).

Polystomella poeyana d'Orbigny, 1839, in de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminiferes", p. 55, Pl. 6, Figs. 25, 26.

This species occurred in all collections. It was quite rare, with a maximum frequency of five percent at station 1 of the February 9th, 1963 collection. Its distribution was inversely related (r = -0.503) to temperature in the August 14th, 1962 collection. The correlation coefficient was significant, but not numerically high so the importance of this parameter to its distribution was not clear.

Elphidium sagrum (d'Orbigny), 1839

Polystomella sagra d'Orbigny, 1839, in de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminiferes", p. 55, Pl. 6, Figs. 19, 20.

This species occurred as a single specimen at station 2 of the August 14th, 1962 collection.

SUPERFAMILY ORBITOIDACEA Schwager, 1876

FAMILY PLANORBULINIDAE Schwager, 1877

GENUS PLANORBULINA d'Orbigny, 1826

Planorbulina mediterranensis d'Orbigny, 1826

Planorbulina mediterranensis d'Orbigny, 1826, Ann. Sci. Nat., vol. 7, p. 280, No. 2, Pl. 14, Figs. 4-6.

This species occurred as a single specimen at station 1 of the August 14th, 1962 collection.

SUPERFAMILY CASSIDULINACEA d'Orbigny, 1839

FAMILY NONIONIDAE Schultze, 1854

SUBFAMILY NONIONINAE Schultze, 1854

GENUS NONION de Montfort, 1808

Nonion depressulum (Walker and Jacob), 1798

Nautilus depressulum Walker and Jacob, 1798, in Adam's Essays, Kanmacher's ed., p. 641, Pl. 14, Fig. 33.

This species occurred in the August 14th and 20th, 1962 collections. It was very rare, with a maximum frequency of three percent at station 10 of the August 14th, 1962 collection.

Nonion grateloupi (d'Orbigny), 1826

Nonionina grateloupi d'Orbigny, 1826, Ann. Sci. Nat., vol. 7, p. 294, No. 19.

This species occurred in the August 14th and 20th, 1962 collections. Only three specimens were found. One occurred at station 10 of the August 14th, 1962 collection and two were found at station 2 of the August 20th, 1962 collection.

REFERENCES CITED

Baars, D.L. 1963. Petrology of carbonate rocks. in Shelf carbonates of the Paradox Basin, Symp. Fourth Field Conf. Four Corners Geol. Soc.; 101-129.

Baas Becking, L.G.M., Kaplan, I.R., and Moore, D. 1960. Limits of the natural environment in terms of pH and oxidation-reduction potentials. Jour. Geology, 68; 243-284.

Benda, W.K., and Puri, H.S. 1962. The distribution of foraminifera and Ostracoda off the Gulf coast of the Cape Romano area. Trans. Gulf Coast Assoc. Geol. Soc., 12; 303-341.

Bock, W.D. (1961). The benthonic foraminifera of southwestern Florida Bay. Unpublished M.S. thesis, Univ. Wisconsin.

Ginsburg, R.N. 1956. Environmental relationship of grain size and constituent particles in some south Florida carbonate sediments. Amer. Assoc. Petr. Geol., Bull, 40; 2384-2426.

________, Ed. 1964. South Florida carbonate sediments. Geol. Soc. America Guidebook, 1964 Annual Meeting; 1-72.

________, and Lowenstam, H.A. 1958. The influence of marine bottom communities on the depositional environment of sediments. Jour. Geology, 66; 310-318.

Gorsline, D.S. 1963. Environment of carbonate deposition Florida Bay and Florida Straits. in Shelf carbonates of the Paradox Basin, Symp. Fourth Field Conf. Four Corners Geol. Soc.; 130-143.

Gould, S.J. 1967. Evolutionary patterns in pelycosaurian reptiles: a factor-analytic study. Evolution, 21; 385-401.

Imbrie, John. 1963. Factor and vector analysis programs for analyzing geologic data. Tech. Rpt. No. 6, ONR Task No. 389-135, Office of Naval Research, Geography Branch; 1-83.

______, and van Andel, Tj. H. 1964. Vector analysis of heavy-mineral data. Geol. Soc. Americana, Bull., 75; 1131-1156.

Lindblom, G.P., and Lupton, M.D. 1961. Microbiological aspects of organic geochemistry. Dev. Indust. Microbiol., 2; 9-22.

Lloyd, R.M. 1964. Variation in the oxygen and carbon isotope ratios of Florida Bay mollusks and their environmental significance. Jour. Geology, 72; 84-111.

Loeblich, A.R., and Tappan, H. 1954. Emmendation of the foraminiferal genera Ammodiscus Reuss, 1862, and Involutina Terquem, 1862. Jour. Washington Acad. Sci., 44; 306-310.

______. 1964. Sarcodina: chiefly "Thecamoebians" and Foraminiferida. Treatise invert. paleont., R.C. Moore, ed., Pt. C, Protista 2. Geol. Soc. America and Univ. Kansas Press; 1-900.

Lynts, G.W. (1961). Distribution of recent foraminifera in upper Florida Bay and associated sounds. Unpublished M.S. thesis, Univ. Wisconsin.

______. 1962. Distribution of recent foraminifera in upper Florida Bay and associated sounds. Contr. Cushman Found. Foram. Res., 13; 127-144.

______. 1965. Observations on some Florida Bay foraminifera. Contr. Cushman Found. Foram. Res., 16; 67-69.

______. 1966a. Relationship of sediment-size distribution to ecologic factors in Buttonwood Sound, Florida Bay. Jour. Sed. Petrology, 36; 66-74.

______. 1966b. Variation of foraminiferal standing crop over short lateral distances in Buttonwood Sound, Florida Bay. Limnol. Oceanogr., 11; 562-566.

Manson, Vincent, and Imbrie, J. 1964. Fortran program for factor and vector analysis of geologic data using an IBM 7090 or 7094/1401 computer system. Spec. Distr. Publ. 13, Kansas State Geol. Surv.; 1-46.

Phleger, F.B. 1960. Ecology and distribution of recent foraminifera. Johns Hopkins Press. Baltimore; 1-297.

Scholz, S.A. (1962). The distribution of recent foraminifera in Hawk Channel, Florida. Unpublished M.S. thesis, Univ. Wisconsin.

Shenton, E.H. 1957. A study of the foraminifera and sediments of Matogorda Bay, Texas. Trans. Gulf Coast Assoc. Geol. Soc., 7; 135-150.

Smith, S.L. (1964). Distribution of recent foraminifera in lower Florida Bay. Unpublished M.S. thesis, Univ. Wisconsin.

Streeter, S.S. (1963). Foraminifera in the sediments of the northwestern Great Bahama Bank. Unpublished Ph.D. thesis, Columbia Univ.

_____. 1964a. Foraminifera in the sediments of the northwestern Great Bahama Bank (abstract). Geol. Soc. America, Spc. Paper 76; 160.

_____. 1964b. Foraminiferal distributions on the Orinoco-Trinidad-Paria Shelf - A restudy using vector analysis (abstract). Program Geol. Soc. America Annual Meeting, 1964; 200.

Taft, W.H., and Harbaugh, J.W. 1964. Modern carbonate sediments of southern Florida, Bahamas, and Espiritu Santo Island, Baja California: a comparison of their mineralogy and chemistry. Stanford Univ. Publ., geol. sci., 8(2); 1-133.

Walton, W.R. 1952. Techniques for recognition of living foraminifera. Contr. Cushman Found. Foram. Res., 3; 56-60.

Wilcoxon, J.A. 1964. Distribution of foraminifera off the southern Atlantic coast of the United States. Contr. Cushman Found. Foram. Res., 15; 1-24.